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Research Article

Allocytoplasmic restorers and performance of hybrids in rice (*Oryza sativa* L.)

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Abstract
Combining ability analysis for yield and quality traits of 54 rice hybrids developed by crossing three CMS lines and eighteen restorers in L x T design were evaluated in RBD. The magnitude of additive genetic variance (σ^2A) was higher than dominance variance for days to 50% flowering, effective tillers, kernel length after cooking and volume expansion ratio indicating the predominance of additive gene action. However, for the rest of the characters non additive gene action was predominant. The relative contribution of testers were high for days to 50% flowering(79.6%), self fertility (72.8%) and flag leaf length (79.9%), indicating influence of parents and interaction contribution (L x T) was high for filled seeds/panicle, yield/plant (57.0%) and hulling percent (63.5%). Among the lines 68897A showed significant *gca* effects in the desirable direction and identified as best combiner for yield/plant, days to 50% flowering, effective tillers, panicle density, hulling percent, head rice recovery, kernel width after cooking, water uptake and volume expansion ratio, while 79156A for self fertility, filled seeds/panicle and panicle length. Among the male parents RR15 was found to be good combiner for panicle length, filled seeds/panicle, unfilled seeds/panicle, self fertility, test weight, yield/plant and RR 23 for effective tillers, panicle length and head rice recovery. The cross combinations 68897 A x RR 23, 68897 A x RR 32, 68897 A x RR55 and 79156 A x RR3 recorded significant *sca* effects for yield/plant and were relatively better performed for desired yield and quality traits based on *sca* effects, per se performance and *gca* effects of parents.

Key words: Rice, Combining ability, *gca, sca*, Quality, Hybrids

INTRODUCTION

Rice is the principal food crop and most extensively grown cereal crop in the tropical and subtropical regions of the world. Today rice has a special position and a source of providing more than 75% of the Asian population and more than three billion of world population meals which represents 50-80% of their daily calorie intake (Khush, 2005). There is an urgent need to increase rice production to meet the requirements of over growing population. The development of hybrids with a yield advantage of 30% over the existing hybrids is the best option for increasing production and productivity. Therefore performance of the hybrids depends on choice of the potential parents for exploitation of heterosis. Combining ability analysis is a powerful tool for estimating the value of a parent to produce superior hybrids, provides information about the nature and magnitude of gene effects governing various traits. Its role is important to decide parents, crosses and appropriate breeding procedures to be followed to select desirable segregants (Salgotra *et al.,* 2009). Keeping this in view, the present investigation was undertaken to study the combining ability in rice to identify superior hybrid combinations for yield and quality traits.

MATERIALS AND METHODS

The present study was conducted between 2016 and 2017 in the research farm of Regional Agricultural Research Station, Warangal, Telangana state. The material for the study comprised of three Cytoplasmic Male Sterile lines 79156A, 79128A and 68897A and eighteen restorers RR3, RR15, RR17, RR23, RR32, RR50, RR55, RR65, WGL-347, WGL-616, WGL-674, WGL-676, WGL-705, WGL-739, WGL-810, WGL-1063, MTU1156 and MTU 11-320-20.The above first eight restorers were newly developed restorer lines through allocytoplasmic restorer (R x R) development programme through recombination breeding and other ten restorers were from advanced breeding lines. Staggered sowing of the parents was taken up to facilitate synchronization in flowering among female and male parents. Crossing block was raised during *Rabi*, 2016 and each line was crossed with 18 testers in Line x Tester mating design of Kempthorne, (1957) to develop hybrids. The F_1 seed of 54 cross combinations was planted along with 21 parents (3 CMS lines and 18 restorers) with a spacing of 20 x 15 cm in randomized block design with two replications during *kharif*, 2017. Recommended package of practices was adopted. Twenty five days old seedlings were transplanted single plant per hill in two rows of 1.2 m length. The performance of F_1 hybrid combination and their parents were evaluated by recording observations on ten randomly selected plants from each genotype on the following attributes as per the standard evaluation system *i,e* plant height (cm), panicle length (cm), effective tillers/plant, flag leaf length (cm), flag leaf width (cm), panicle density (g), filled seeds/panicle, unfilled seeds/panicle, self fertility (%), test weight (g), grain yield/plant except days to 50% flowering which was computed on plot wise basis. Due to male sterility nature of the CMS lines or female lines their corresponding maintainer lines were used for studying yield and quality traits.

Data were also recorded on physical and chemical quality characters *viz.,* hulling percent (%), milling percent (%), head rice recovery (%), kernel length (mm), kernel width (mm), length/breadth ratio, kernel length after cooking (mm), kernel width after cooking (mm), kernel elongation ratio, alkali spreading value, volume expansion ratio and water uptake (ml). Observations on hulling and milling were taken with the help of Satake company make laboratory huller (Type THU35A) and polisher (TypeTMO5). Data on head rice recovery was recorded. Kernel length and kernel width of 20 whole milled rice were measured by means of dial calliper and length and breadth ratio were computed as per Murthy and Govindaswamy (1967). Kernel elongation ratio was determined by soaking 5 g of whole milled rice in 12 ml distilled water for 10 minutes and later cooked for 15 minutes in the water bath. Observations on the length and breadth of cooked kernels and elongation ratio were recorded with the help of a graph sheet to quantify cooking traits, while water uptake, volume expansion ratio and alkali spreading value by following the standard procedures. Combining ability analysis for various yield and quality traits was accomplished by the method suggested by Kempthorne (1957) through windostat version 9.2 from indostat services Hyderabad (India). Character wise estimation of *gca* effects of parental lines and *sca* effects of cross combinations were evaluated by t-test.

RESULTS AND DISCUSSION

The analysis of variance showed significant variation due to genotypes for all the yield and quality traits studied (**Table 1**). The parents also exhibited significant differences for the characters under study. The lines differed significantly among themselves for most of the important characters. Testers also differed significantly for all the characters studied. Line x Tester interaction was significant for all the characters except effective tillers, unfilled seeds/panicle, hulling percent, kernel elongation ratio indicated presence of wide genetic variation among lines and testers. Female parents interacted significantly with the male parents provided a direct test indicating that non additive variance was important for many of the characters. These results are in conformity with the findings of Akter *et al.* (2010) and Thakare *et al.* (2013),Rukmini Devi *et al.* (2018) Ambikabathy *et al*.(2019) and Buelah *et al*.(2020) who also reported that female parents interacted significantly with the male parents. The parents *Vs* hybrids comparison was found to be significant for all the yield and quality traits except effective tillers, panicle density, filled seeds/panicle, hulling percent, kernel width, kernel elongation ratio and alkali spreading value indicating a substantial amount of heterosis in hybrids. The proportional contribution of female parents, male parents and their interaction towards total variance was also estimated (**Table 1**). Female parents played a important role towards volume expansion ratio and male parents were important for days to 50% flowering, plant height, flag leaf length, flag leaf width, panicle density, unfilled seeds/panicle, self fertility, test weight, kernel length, kernel width, length/breadth ratio, kernel length after cooking and alkali spreading value revealing the predominant influence for these traits. The contribution of paternal and maternal interaction (female x male) was observed to be best in proportion for the traits effective tillers, filled seeds /panicle, yield/plant, hulling percent, milling percent, head rice recovery, kernel width after cooking, kernel elongation ratio and water uptake indicating that these characters are influenced by non additive gene action. The high contribution of maternal and paternal interaction in rice for the traits yield/plant, effective tillers, head rice recovery, kernel width after cooking also reported by Showkat *et al*. (2015). Combining ability variances in the present study (**Table 2**) revealed that magnitude of additive genetic variance (σ^2A) was higher than dominance variance (σ^2D) for the characters days to 50% flowering, effective tillers, flag leaf width, kernel length after cooking, kernel width after cooking and volume expansion ratio indicating predominance of additive gene action. Similar views were expressed by Srinivas *et al*. (2015) and Rukmini Devi *et al.* (2017) for kernel length after cooking and kernel width after cooking, Salgotra *et al*. (2009) and Showkat *et al*. (2015) for days to 50 % flowering and Asvin Kirubha *et al*.(2019) for kennel length after cooking. However, for rest of the traits *viz*., plant height, panicle length, flag leaf width, panicle density, filled seeds/panicle, self fertility, test weight, yield/plant, unfilled seeds/panicle,

Table 1 a. Analysis of variance of combining ability for yield and yield components in rice

Source of variation	D.F	Days to 50% flowering	Effective tillers/m2	Plant height	Panicle length	Flag leaf length	Flag leaf width	Panicle density	Filled seeds / panicle	Unfilled seeds/panicle	Self fertility	Test weight	Yield/plant
Replications	1	1.706	0.026	19.44	2.574	0.201	0.053	0.009	34.56	29.92	4.678	2.2	1.38
Treatments	74	85.607**	1.860**	142.723**	8.333**	49.102**	0.209**	4.244**	3814.159**	744.507**	98.357**	15.176**	86.321**
Parents	20	122.407**	1.545**	194.113**	7.861**	43.718**	0.271**	5.974**	3033.373**	380.930**	65.981**	27.828**	96.264**
Parent(line)	2	1.166	0.166	6.019	0.735	5.226	0.131*	4.329**	1138.166	42	34.277*	15.581**	5.54
Parent(tester)	17	111.915**	1.776**	118.737**	8.395**	42.123**	0.237**	4.305**	2298.816**	443.066**	64.282**	29.412**	56.210**
Parent (line x tester)	1	543.253**	0.321	1851.689**	13.028**	147.813**	1.133**	37.630**	19311.253**	2.48	158.285**	25.396**	958.620**
Parents vs. Crosses	1	1290.150**	0.038	1141.146**	97.884**	253.692**	2.680**	0.645	1530.88	802.287**	136.904**	68.19**	26.156*
Crosses	53	48.993**	2.014**	104.492**	6.821**	47.274**	0.139**	3.659**	4151.875**	880.616**	109.847**	9.402**	83.705**
Line effect	2	42.583	12.027**	67.668	7.907	82.571	0.016	3.469	7939.361	9.694	30.51	21.891*	345.822*
Tester effect	17	121.647**	2.259	175.740*	13.131**	75.640*	0.347**	7.526**	5032.593	1856.647**	249.487**	13.399*	71.47
Line x tester effect	34	13.044**	1.302**	71.035**	3.602**	31.014**	0.042	1.737**	3488.723**	443.831**	44.693**	6.669**	74.399**
Error	74	2.139	0.391	11.517	1.161	5.927	0.039	0.228	418.411	74.26	10.81	0.742	5.786
Total	149	43.59	1.118	76.733	4.732	27.331	0.123	2.221	2102.313	406.8	54.25	7.921	45.75
Contribution (%)													
Lines		3.27	22.5	2.44	4.37	6.59	0.44	3.57	7.28	0.04	1.048	8.78	65.59
Testers		79.6	35.9	3.9	61.7	51.32	79.9	65.96	38.8	67.6	72.8	45.7	27.3
L x T		17.07	41.4	43.6	33.8	42.08	19.65	30.45	53.9	32.3	26.10	45.5	57.01

* and ** significant at 5% and 1% level, respectively

Table 1b. Analysis of variance of combining ability for quality traits in rice

Source of Variation	DF	Hulling recovery	Milling recovery	Head rice recovery	Kernel length	Kernel width	L/ B ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elongation ratio	Alkali spreading value	Volume expansion ratio	Water uptake
Replications	1	1.622	11.206	12.557	2E-05	0.02	0.06	0.026	0.00015	0.001	0.106	0.015	11.2
Treatments	74	7.179**	64.713**	255.455**	0.350**	0.035**	0.160**	0.543**	0.098**	0.011**	1.124**	2.255**	10256.976**
Parents	20	7.021**	87.220**	270.441**	0.428**	0.090**	0.269**	0.781**	0.1215**	0.008**	1.078**	0.275**	11770.773**
Parent(line)	2	5.431	39.781**	111.671**	0.131*	0.024*	0.283**	0.673**	0.140**	0.004	0.166	0.186	1754.166**
Parent(tester)	17	7.619**	95.508**	270.465**	0.426**	0.093**	0.181**	0.736**	0.12159**	0.009**	0.797*	0.267**	8616.013**
Parent (line x tester)	1	0.04	41.204*	587.583**	1.046**	0.178**	1.746**	1.778**	0.082*	0.00009	7.682**	0.600**	85434.920**
Parents vs. Crosses	1	6.762	109.516**	1610.613**	2.735**	0.00013	0.566**	1.599**	1.732**	0.013	0.251	24.609**	143140.326**
Crosses	53	7.246**	55.374**	224.231**	0.276**	0.014**	0.111**	0.433**	0.059**	0.012**	1.158**	2.581**	7178.499**
Line effect	2	13..56	103.4	378.5	0.074	0.009	0.025	1.752**	0.410**	0.03	2.861*	28.695**	40028.481**
Tester effect	17	6.642	52.4	327.264*	0.559**	0.022*	0.209**	0.697**	0.037	0.006	1.651*	1.196	7428.832
Line X Tester effect	34	7.177**	54.036**	163.638**	0.146**	0.011*	0.067**	0.224**	0.049**	0.014**	0.812**	1.737**	5120.981**
Error	74	2.018	6.346	3.589	0.032	0.005	0.028	0.096	0.018	0.003	0.417	0.076	267.3
Total	149	4.578	35.36	128.7	0.19	0.02	0.094	0.318	0.058	0.007	0.766	1.158	5226.9
Contribution (%)													
Lines		7.06	7.04	6.67	1.01	2.53	0.85	15.25	26.0	9.25	9.31	41.94	21.04
Testers		29.39	30.3	46.8	4.9	49.2	60.19	51.58	20.28	15.87	45.7	17.87	33.9
L Xt		63.50	62.6	46.8	34.0	43.2	389	33.15	53.71	74.8	44.9	43.07	45.7

* and ** significant at 5% and 1% level, respectively

Table 2a. GCA and SCA variance for yield and yield components in rice

Source of Variation	Days to 50% flowering	Plant height	Plant length	Effective tillers/ m^2	Flag leaf length	Flag leaf width	Panicle density	Filled seeds / panicle)	Unfilled Seeds/ panicle	Self fertility	Test weight	Yield/ plant
σ^2GCA (Lines)	1.1235	1.539	0.187	0.3232**	2.129	0.006	0.090	208.9	-1.79	0.547	0.587*	9.445*
σ^2GCA (Testers)	19.918**	27.37**	1.995**	0.3114	11.618*	0.0513*	1.216**	769.03	297.06**	39.77**	2.109*	10.948*
σ^2A	7.61	10.49	0.89	0.64	6.96	0.0136	0.50	577.76	8.18	12.3	1.60	19.32
^{2}D	5.45	29.75	1.22	0.45	12.5	0.0017	0.75	1535.6	184.7	16.9	2.96	34.3
σ^2GCA	3.808	5.247**	0.4456**	0.3215**	3.484*	0.0068**	0.251**	288.9**	40.90**	6.151**	0.804**	9.660**
σ^2SCA	5.452	29.75**	1.2208**	0.4456**	12.54**	0.0017	0.755**	1535.1**	184.78**	16.939**	2.963*	34.30**
σ^2GCA/ σ^2 SCA	1.196	0.176	0.730	0.760	0.277	7.910	0.665	0.376	0.442	0.726	0.543	0.563

* and ** significant at 5% and 1% level, respectively

Table 2b. GCA and SCA variance for quality traits in rice

Source of Variation	Hulling recovery	Milling recovery	Head rice recovery	Kernel length	Kernel width	L/ B ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elonga- tion ratio	Alkali spreading value	Volume expan- sion ratio	Water up take
σ^2GCA (Lines)	0.3206	2.696	10415	0.0012	0.0001	-0.0001	0.0460*	0.0109**	0.0007	0.0679*	1104.4*	0.7950**
σ^2GCA (Testers)	0.7707	7.675	53.94*	0.0878**	0.0028*	0.0301**	0.1001**	0.0032	0..00004	0.2057*	1193.57	0.1867*
σ^2A	1.53	6.81	33.2	0.027	0.001	0.008	0.107	0.019	0.001	0.175	1.41	2234
σ^2D	10.3	23.8	80.02	0.057	0.0026	0.01	0.063	0.0156	0.005	0.197	0.830	2426
σ^2GCA	0.3849*.	3.407*	16.63**	0.0135**	0.0005**	0.0042**	0.0537**	0.0098**	0.0007	0.0876**	1117.020*	0.7081*
σ^2SCA	2.579**	23.40**	80.02**	0.0570**	0.0026*	0.0195**	0.0636**	0.0156**	0.0054*	0.1973*	2426.8*	0.8306**
σ^2GCA/ σ^2 SCA	0.298	0.2858	0.4157	0.475	0.1905	0.4324	1.688	1.249	0.2575	0.8877	0.9207	1.705

* and ** significant at 5% and 1% level, respectively

hulling percent, milling percent, head rice recovery, kernel length, kernel width, length/breadth ratio, kernel elongation ratio, alkali spreading value and water uptake, the value of σ^2A is lower than σ^2D indicating the predominance of non additive gene action. The presence of non additive genetic variance offer scope for exploitation of heterosis. The predominance of non additive gene action for grain yield/plant and important yield and quality traits has been reported by Satyanarayana *et al.* (2000). The existence of both additive and non additive type of gene action for yield and quality traits has also been reported by Showkat *et al. (*2015) and Rukmini Devi *et al.*(2018).

Both *gca* and *sca* effects were estimated for yield and quality traits (**Table 3, and 4**). The estimates of combining ability effects aid in selecting desirable parents and crosses as well as suitable breeding procedures for further improvement of various yield and quality traits in rice. Regarding *gca* effects, the negative effects for days to 50% flowering, plant height, flag leaf width, kernel width and kernel width after cooking are considered desirable whereas, positive effects are desirable for other yield and quality traits. The *gca* attributed to additive gene effects and additive x additive epistasis and theoretically fixable, on the other hand *sca* attributable for non additive gene action may be due to dominance or epistasis or both and are non fixable. `The presence of non additive genetic variance is the primary justification for initiating hybrid programme (Cockarham,1961; Pradhan *et al.,* 2006).

Earliness being a desirable trait and helps to develop early hybrids. Significant negative *gca* was exhibited by the line 68897A (-1.130) while, among testers RR32, RR3, RR17 and MTU 11-320-20 has showed good *gca* in desired direction. The CMS lines 79156 A and restorers RR15, RR23, RR55, RR65, WGL676 and WGL 705 were recorded as poor combiners because they possessed significant positive *gca* effect. (**Table 3**).The hybrids 79128 A x WGL-739, 68897 A x WGL 676, 79128 A x RR 3, 68897 A x MTU 1156 and 79156 A x MTU11-320-20 showed significant negative *sca* effects (**Table 4**).Total number of productive tillers per plant generally associated with high productivity. The significant positive value of *gca* effect for effective tillers amongst

Table 3a. Estimates of general combining ability effects for yield and yield components in rice

Source of Variation	Days to 50% flowering	Effective tillers/ m^2	plant height	Panicle length	Flag leaf length	Flag leaf width	Panicle density	Filled seeds / panicle)	Unfilled seeds/ panicle	Self fertility	Test weight	Yield/ Plant
Lines												
79156A	1.028**	-0.361**	0.126	0.534**	0.647	0.012	-0.290**	7.583*	-0.556	1.058	-0.406**	-0.171
79128A	0.111	-0.306	1.304*	-0.344	1.083*	0.013	-0.0337	9.528**	0.083	-0.434	0.899**	-3.010**
68897A	-1.130**	0.667**	-1.430*	-0.190	-1.731**	-0.025	0.328**	-17.111**	0.472	-0.624	-0.493**	3.181**
SE ±	0.2438	0.104	0.56	0.179	0405	0.33	0.079	3.40	1.92	0.548	0.143	0.40
Testers												
RR3	-10.278**	-0.917**	-6.005**	-1.947**	-1.208	-0.371**	1.633**	-27.472**	-23.056**	7.751**	-0.173	-2.799**
RR15	5.222**	-0.417	5.779**	2.087**	1.275	0.495**	-0.578**	47.361**	-19.722**	9.148**	-1.223**	3.568**
RR17	-5.278**	-0.250	-1.821	-1.363**	-1.425	-0.888	-0.384	-14.139	-19.556**	6.026**	1.977**	2.534*
RR23	3.222**	1.750**	2.279	1.603**	4.808**	-0.105	0.004	2.028	-7.556**	3.508*	-1.640**	4.768**
RR32	-10.611**	0.417	-6.988**	-2.430**	-3.058**	0.062	3.401**	-51.806**	30.111**	-11.276**	-2.056**	-6.482**
RR50	0.556	-0.083	3.445*	2.570**	6.275**	0.149	-0.873**	12.528	-9.389*	4.518**	2.510**	-1.432
RR55	2.222**	0.750**	-8.805**	0.012	4.208**	-0.125	1.176**	-36.472**	34.111**	-13.644**	-0.140	-2.832**
RR65	4.389**	-0.250	6.279**	1.203**	2.108*	0.329**	-0.061	-7.139	12.944**	-1.744	1.177**	1.101
WGL347	1.389*	-0.250	3.712**	-0.263	-0.558	0.029	-0.811**	18.028*	-6.556	3.399*	-1.940**	-2.699**
WGL616	3.222**	0.083	3.912**	0.703	2.975**	-0.021	-0.454*	19.028*	-12.889**	4.046**	-0.156	-1.066
WGL674	0.722	0.083	1.545	-0.397	-1.225	-0.005	-0.538**	9.694	28.444**	-8.676**	-2.023**	2.318*
WGL676	3.389**	0.750**	-3.005*	-0.363	-1.392	0.029	-0.243	7.361	2.944	-0.861	-0.840*	4.084**
WGL705	1.722**	-0.083	-3.555*	-0. 130	-0.992	-0.271**	0.176	-5.806	1.444	-0.806	-0.340	3.001**
WGL739	-0.944	-0.583*	-2.721	-0.797	-2.258*	-0.171 *	-0.002	-2.472	12.944**	-5.644**	-0.656	-3.666**
WGL810	0.056	-0.250	-0.321	-0.130	0.242	0.045	-0.397*	-23.806**	-8.389*	-0.176	1.360**	-5.232**
WGL1063	1.722**	-0.583*	12.579**	2.337**	3.242**	0.462**	-1.713**	71.694**	-11.389**	3.471*	0.560	4.368**
MTU1156	1.222*	0.083	-1.821	-1.163*	-5.725**	-0.305**	0.028	-15.639	6.944	-3.313*	2.044**	0.334
MTU II-320-20	-1.944**	-0.250	-4.488**	-1.530**	-7.292**	-0.138	-0.364	-2.972	-11.389**	4.274**	1.560**	0.134
SE ±	0.5971	0.255	1.385	0.44	0.993	0.080	0.195	8.35	3.51	1.31	0.351	0.982

* and ** significant at 5% and 1% level, respectively

the female and male parents was observed in 68897 A and RR 23, RR 50 and WGL 676 which could be utilized for evolving hybrids with more effective tillers/plant. Showkat *et al.* (2015) also reported 68897 A was good combiner for effective tillers (**Table 3a**). The crosses 79156 A x MTU 1156, 68897 A x RR 23 and 68897 A x RR 55 recorded significant desirable estimates of *sca* effects. Dwarf plant stature is desirable to develop semi dwarf high yielding hybrids which will be lodging resistant and fertilizer responsive. Among the females 68897A and among the testers RR 55, RR 32, RR 3, MTU 11-320-20, WGL 705 and WGL 676 recorded significant *gca* effects in desired direction. The hybrids 79128 A x RR 3 and 68897 A x RR 23, showed significant negative *sca* effects (**Table 4a**).Longer panicle length is associated with more number of spikelets per panicle resulting in higher productivity. Significant positive *gca* effect, among lines was exhibited by 79156 A and testers *viz.*, RR 50, WGL 1063, RR 15, RR 23 and RR 65 (**Table 3a**). Only four hybrids 68897 A x WGL 616 and 68897 A x MTU-11-320 exhibited significant *sca* effect for panicle length. The number of filled seeds per panicle is one of the most important yield component in rice. Among the lines 79128 A, 79156 A and among male parents WGL 1063, RR 15, WGL 616 and WGL 347 and RR 65 exhibited significant positive *gca* effect which could be utilized for evolving more filled grains/panicle, whereas nine hybrids recorded significant *sca* effects *viz.,* 68897 A x WGL 810, 68897 A x MTU 1156, 68897 A x MTU 11-320 and 79156 A x RR 23 (**Table 4**).

Table 3b. Estimates of general combining ability effects for quality traits in rice

Source of Variation	Hulling recovery	Milling recovery	Head rice recovery	Kernel length	Kernel width	L/ B ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elonga-tion ratio	Alkali spreading value	Volume expan-sion ratio	Water uptake
Lines												
79156A	-0.684**	-1.956***	-1.336**	0.050	0.003	0.022	0.232**	0.100**	0.028**	0.250*	-0.593**	-36.130**
79128A	0.182	0.941*	-2.361**	-0.039	-0.018	0.008	-0.025	0.012	0.003	-0.306**	-0.434**	29.593**
68897A	0.502*	1.016*	3.697**	-0.011	0.015	-0.030	-0.207**	-0.112**	-0.030**	0.056	1.027**	6.537*
SE ±	0.236	0.419	0.317	0.03	0.92	0.028	0.051	0.022	0.01	0.107	0.04	2.72
Testers												
RR3	-0.018	-3.390**	-7.747**	0.016	-0.040	0.078	-0.013	-0.061	-0.009	-0.361	-0.326**	42.509**
RR15	-0.801	4.310**	10.719**	-0.447**	0.070*	-0.357**	-0.338*	0.039	0.035	-0.194	-0.259*	-49.157**
RR17	0.016	-5.173**	-14.331**	0.059	0.081*	-0.097	0.012	-0.044	-0.014	0.639*	-0.759**	17.343*
RR23	0.432	0.327	2.653**	-0.036	-0.029	0.031	-0.263*	0.006	-0.042	-0.194	-0.259*	28.343**
RR32	-2.218**	-4.256**	-9.214**	-0.894**	-0.045	-0.417**	-0.971**	0.164**	0.021	-0.361	-0.393**	-40.824**
RR50	0.432	-1.306	4.019**	0.393**	0.078*	0.074	0.346**	0.081	-0.020	0.139	-0.576**	8.343
RR55	0.416	0.260	-0.231	0.373**	-0.012	0.219**	0.312*	-0.061	-0.017	-0.528	-0.459**	-0.824
RR65	0.149	0.577	-0.147	-0.167*	0.020	-0.124	-0.088	0.098	0.03	-0.694*	-0.059	-19.157**
WGL347	0.316	-0.390	-2.064*	-0.221**	-0.034	-0.071	-0.196	-0.011	0.01	-0.028	0.341**	9.176
WGL616	1.699**	6.527**	11.753**	0.071	-0.042	0.103	0.171	0.081	0.015	0.139	0.257*	23.343**
WGL674	-1.384*	-0.490	-0.514	0.074	-0.064*	0.149*	-0.028	-0.144*	-0.019	-0.361	0.391**	-30.824**
WGL676	0.099	1.460	6.003**	0.029	-0.102**	0.194**	0.537 **	0.106	0.086**	1.139**	0.091	64.176**
WGL705	0.766	2.610*	3.053**	0.276**	-0.029	0.198**	0.212	-0.044	-0.019	0.806**	0.291*	-13.324
WGL739	0.749	-0.223	5.269**	0.333**	0.008	0.163*	0.312*	-0.061	-0.014	-0.361	0.824**	-5.824
WGL810	1.732**	2.844**	8.853**	0.101	-0.005	0.059	0.096	-0.011	-0.007	0.639*	0.441**	-29.157**
WGL1063	-0.318	0.510	-10.797**	-0.011	0.143**	-0.234**	-0.304*	-0.044	-0.055*	-0.694*	-0.326**	-62.491**
MTU1156	-1.868**	-3.410**	-2.747**	0.016	-0.039	0.073	0.062	-0.077	0.006	0.139	0.107	54.176**
MTU II-320-20	-0.201	-1.056	-4.531**	0.036	0.038	-0.041	0.137	-0.019	0.015	0.139	0.674**	4.176
SE ±	0.580	1.02	0.773	0.07	0.031	0.069	0.127	0.055	0.02	0.263	0.11	6.67

* and ** significant at 5% and 1% level, respectively

Panicle density is also a very important yield contributing character in rice. The female parent 68897 A and male parents RR 32, RR 55, and RR 3 were good general combiners by recording significant positive *gca* effects indicating positive alleles for panicle density which could be fixed in subsequent generations(**Table 3**). Significant *sca* effects were exhibited by ten hybrids and 68897 A x RR 55, 79128A x MTU 1156, 68897 A x RR 65 and 68897 A x RR 32 recorded higher *sca* effects. Chaffy-ness is undesirable in case of hybrids to get more yield. For this trait, 79156 A among the lines and RR 3, RR 15, RR 17, WGL 616, WGL 1063, MTU 11-320-20, RR 50 and RR 23 recorded negative *gca* effects and the hybrids 68897 A x RR 55, 79156 A x WGL 674, 79156 A x WGL 676, 79156 A x MTU 1156 and 79156 A x MTU11-320 manifested significant negative *sca* effects in desirable direction (**Table 4**). Self fertility is generally associated with higher productivity. Interestingly the same lines, testers and hybrids which showed negative *gca* and sca effects for unfilled seeds per panicle and exhibited significant positive *gca* and *sca* effects for self fertility percentage.

Test weight is also a very important yield contributing trait in rice. The line 79128 A and male parents RR 50, MTU 1156, RR 17, WGL 810, RR 65 and MTU-11-320 were identified as good general combiners for this trait (**Table 3**). Among 54 hybrids, twelve hybrids 79128 A x MTU 1156, 79156 A x RR 23, 79156 A x RR 50 recorded significant *sca* effect (**Table 4**).For grain yield/plant significant *gca* effects was recorded by 68997 A among

Table 4a. Estimates of specific combining ability effects for yield and yield components_in rice.

S.No.	Hybrids	Days to 50% flowering	Effective tillers/m²	Plant height	Panicle length	Flag leaf length	Flag leaf width	Panicle density	Filled seeds / panicle)	Unfilled seeds/ panicle	Self fertility	Test weight	Yield/ plant
1	79156AXRR3	4.139**	0.694	11.657**	1.450	5.436**	0.188	-1.343**	28.083	12.556*	-4.679*	-0.760	6.138**
2	79156AXRR15	0.639	0.194	1.274	-0.234	0.653	-0.079	0.792*	-28.750	-0.278	-1.256	-0.360	2.871
3	79156AXRR17	-0.361	0.528	1.774	0.666	0.253	0.205	0.888*	-14.250	3.556	-2.759	-0.060	-6.595**
4	79156AXRR23	-1.361	-1.472**	2.374	0.000	4.419*	-0.079	-1.075**	48.083**	7.556	-1.256	3.506**	-8.529**
5	79156AXRR32	-0.528	-1.139*	-1.859	-1.067	-2.214	0.055	-0.472	-26.083	27.389**	-1.333	-0.277	-9.979**
6	79156AXRR50	-1.694	-0.639	-3.693	1.033	4.353*	-0.132	0.862*	-1.447	-5.111	2.319	-3.194**	-2.629
7	79156AXRR55	0.639	-0.472	-1.443	-1.109	1.419	-0.359*	-1.422**	29.583*	34.389**	-4.894*	0.956	0.071
8	79156AXRR65	-0.028	0.028	-2.226	-1.000	2.119	0.088	-0.185	1.250	-0.944	-3.899	1.340*	-0.162
9	79156AXWGL347	-0.528	0.528	-3.259	-0.034	0.786	0.038	0.175	34.583*	4.056	-0.788	0.106	5.738**
10	79156AXWGL616	-1.861	0.694	-1.959	0.900	0.153	-0.012	0.448	35.583*	-5.611	4.146	0.923	-2.295
11	79156AXWGL674	-0.861	0.194	-3.093	-0.200	-3.547*	-0.079	0.907**	-13.083	-23.444**	5.882*	0.390	5.221**
12	79156AXWGL676	-1.028	-0.472	2.207	0.666	-3.281	-0.120	-0.098	3.250	-13.944*	5.128*	0.306	5.355**
13	79156AXWGL705	-0.861	-0.639	-1.093	0.333	-2.381	-0.162	0.108	6.417	9.556	-3.442	-0.094	2.438
14	79156AXWGL739	1.306	0.361	5.574*	-0.200	-0.314	0.188	-0.348	14.083	-9.944	4.516	1.123	0.605
15	79156AXWGL810	-1.194	0.528	1.174	0.133	-1.814	0.021	0.277	-80.583**	-6.611	-3.707	0.156	2.171
16	79156AXWGL1063	2.139*	-0.139	-2.926	0.366	-3.414	-0.145	0.727*	-51.083**	-12.611*	-4.099	-1.344*	-3.929*
17	79156AXMTU1156	3.639**	1.194**	-1.326	-0.934	-1.347	0.121	-0.258	1.750	-7.944	5.054*	-0.677	1.705
18	79156AX MTU11-320-20	-2.194*	0.028	-3.159	-0.767	-1.281	0.155	0.018	12.583	-12.611*	5.067*	-2.044	1.805
19	79128AXRR3	-2.944**	-0.861	-18.670**	-3.523**	-9.950**	-0.113	0. 359	-10.861	-6.583	2.122	-0.366	-4.623**
20	79128AXRR15	-0.944	-0.361	-0.604	0.794	-0.383	0.021	-0.066	-6.194	-9.917	3.986	-0.366	-2.090
21	79128AXRR17	5.556**	-0.028	4.796	0.244	1.417	0.054	-0.449	13.806	0.917	0.077	-1.716**	8.444**
22	79128AXRR23	1.056	0.472	7.896**	0.977	-0.017	-0.029	0.482	9.639	-1.583	1.141	-1.899**	-3.290
23	79128AXRR32	-0.611	0.306	-0.337	-0.989	2.350	-0.046	-0.809*	22.972	12.750*	-1.281	-0.232	-0.890
24	79128AXRR50	1.722	-0.194	3.330	-0.289	2.517	0.227	-0.421	36.139*	13.750*	-4.684*	1.601*	3.210
25	79128AXRR55	1.056	-0.528	9.280**	1.369	2.483	0.141	-0.539	-19.361	2.750	-3.828	1.401*	-5.890
26	79128AXRR65	0.389	0.472	-0.704	0.077	-2.917	-0.063	-1.133**	36.306*	-0.583	0.567	-1.416*	0.877
27	79128AXWGL347	-0.111	0.472	0.263	1.444	2.950	-0.013	0.502	17.639	2.917	-0.786	-1.149	2.077
28	79128AXWGL616	0.556	-0.361	1.763	1.077	3.717*	0.037	-0.449	14.639	-6.250	4.657	-0.432	9.344**
29	79128AXWGL674	1.056	0.139	1.530	0.477	2.917	0.021	-0.551	23.972	7.417	1.054	-1.866**	-1.990
30	79128AXWGL676	-0.111	-1.028*	2.380	-0.556	1.083	-0.013	-0.271	2.806	2.417	0.259	-0.549	-8.256**
31	79128AXWGL705	1.056	0.306	-1.570	0.011	-1.417	-0.013	0.156	1.472	-1.583	0.859	0.101	-0.973
32	79128AXWGL739	-6.278**	0.306	-8.104**	-1.123	-4.150*	-0.163	0.554	-37.361*	-4.583	-0.223	-0.332	-0.256
33	79128AXWGL810	0.722	0.472	-0.804	0.611	0.750	-0.029	0.594	1.472	3.750	0.204	1.901**	4.710**
34	79128AXWGL1063	-0.944	0.306	-0.404	0.744	3.050	0.054	-0.081	16.472	9.750	0.952	-0.399	3.010
35	79128AXMTU1156	-0.944	-0.361	-0.104	-0.156	-2.483	0.021	1.394**	-62.694**	6.917	-6.134*	3.868**	1.244
36	79128AX MTU11-320-20	-0.278	0.472	0.063	-1.189	-1.917	-0.096	0.726*	-60.861**	-6.750	1.059	1.851**	-4.656**
37	68897AXRR3	-1.194	0.167	7.013**	2.073**	4.514*	-0.075	0.984**	-17.222	-5.972	2.557	1.126	-1.515
38	68897AXRR15	0.306	0.167	-0.670	-0.560	-0.269	0.058	-0.726*	34.944*	10.194	-2.730	0.726	-0.781
39	68897AXRR17	-5.194**	-0.500	-6.570**	-0.910	-1.669	-0.259	-0.439	0.444	-4.472	2.682	1.776**	-1.848
40	68897AXRR23	0.306	1.000*	-10. 270**	-0.977	-4.403*	0.108	0.593	-57.722**	5.972	0.115	-1.607*	11.819**
41	68897AXRR32	1.139	0.833	2.196	2.056**	-0.136	-0.009	1.281**	3.111	-14.639*	2.614	0.509	10.869**
42	68897AXRR50	--0.028	0.833	0.363	-0.744	-6.869**	-0.095	-0.441	-34.722*	-8.639	2.365	1.593*	-0.581
43	68897AXRR55	-1.694	1.000*	-7.837 **	-0.260	-3.903*	0.218	1.961**	-10.222	-37.139**	8.722**	-2.357**	5.819**
44	68897AXRR65	-0.361	-0.500	2.930	0.923	0.797	-0.025	1.318**	-37.556*	1.528	3.332	0.076	-0.715
45	68897AXWGL347	0.639	-1.000*	2.996	-1.410	-3.736*	-0.025	-0.678	-52.222**	-6.972	1.574	1.043	-7.815**
46	68897AXWGL616	1.139	-0.333	0.196	-1.977*	-3.869*	-0.025	0.001	-50.222**	11.861	-8.803**	-0.491	-7.048**
47	68897AXWGL674	-0.194	-0.333	1.563	-0.277	0.631	0.058	-0.356	-10.889	16.028*	-6.936**	1.476*	-3.231
48	68897AXWGL676	4.972**	1.500**	-4.587	-0.110	2.197	0.025	0.369	-6.056	11.528	-5.386	0.243	2.902
49	68897AXWGL705	-0.194	0.333	2.663	-0.344	3.797 *	0.175	-0.264	-7.889	-7.972	2.584	-0.007	-1.465
50	68897AXWGL739	4.972**	-0.667	2.530	1.323	4.464 *	-0.025	-0.206	23.278	14.528*	-4.293	-0.791	-0.348
51	68897AXWGL810	0.472	-1.000*	-0.370	0.744	1.064	0.008	-0.871*	79.111**	2.861	3.504	-2.057**	-6.881**
52	68897AXWGL1063	-1.194	-0.167	3.330	-1.110	0.364	0.091	-0.646	34.611*	2.861	3.147	1.743**	0.919
53	68897AXMTU1156	-2.694*	-0.833	1.430	1.090	3.831 *	-0.142	-1.136**	60.944**	1.028	1.080	-3.191**	-2.948
54	68897AX MTU11-320-20	2.472*	-0.500	3.096	1.956*	3.197	-0.059	-0.744*	48.278**	19.361**	-6.126*	0.193	2.852

* and ** significant at 5% and 1% level, respectively

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Table 4b. Estimates of specific combining ability effects for quality traits in rice.

S.No.	Hybrids	Hulling recovery	Milling recovery	Head rice recovery	Kernel length	Kernel width	L/ B ratio	Kernel length after cooking	Kernel breadth after cooking	Kernel elonga-tion ratio	Alkali spreading value	Volume expan-sion ratio	Water uptake
1	79156AXRR3	1.784	6.290**	8.036**	0.045	-0.078	0.168	-0.390	-0.200*	-0.071	0.417	-0.157	63.630**
2	79156AXRR15	0.018	7.440**	4.069**	-0.122	-0.053	0.013	0.085	0.150	0.051	0.250	0.076	40.296**
3	79156AXRR17	-0.699	-4.627*	-2.131	0.032	0.110*	-0.157	-0.015	0.058	-0.011	-0.583	0.726**	-49.204**
4	79156AXRR23	-1.616	-7.227**	-16.864**	0.277*	-0.005	0.160	0.385	0.158	0.012	0.250	-0.024	-17.204
5	79156AXRR32	-0.816	-5.044**	-0.097	0.220	-0.108	0.298*	-0.432	0.175	-0.136**	-0.083	0.259	-45.537**
6	79156AXRR50	0.584	-2.294	9.319**	0.023	0.039	-0.054	0.001	-0.092	-0.004	0.417	0.443*	7.796
7	79156AXRR55	-2.699**	-5.710**	-7.931**	-0.482**	-0.046	-0.184	0.285	-0.100	0.147**	-0.417	0.476*	-25.537*
8	79156AXRR65	-1.982	-1.977	-7.514**	0.233	-0.048	0.205	-0.065	0.066	-0.069	0.750	0.126	32.796**
9	79156AXWGL347	1.151	1.040	5.653**	0.152	0.030	0.031	-0.082	-0.025	-0.004	0.583	-0.624**	-10.537
10	79156AXWGL616	-0.632	0.073	1.636	-0.050	-0.006	-0.071	0.001	-0.042	0.011	-0.083	0.109	35.296**
11	79156AXWGL674	-0.199	2.540	9.603**	0.172	0.025	0.056	0.105	0.033	-0.016	0.417	-0.224	-55.537**
12	79156AXWGL676	2.718**	3.590*	-3.514 *	-0.078	0.059	-0.159	0.285	0.058	0.069	-0.083	0.326	19.463
13	79156AXWGL705	2.701**	4.190*	-0.414	-0.080	-0.055	0.063	0.335	0.008	0.074	-0.750	-0.024	-65.537**
14	79156AXWGL739	1.318	3.123	7.519**	-0.222	0.034	-0.182	0.285	0.100	0.089*	-0.583	-0.107	-5.537
15	79156AXWGL810	0.384	4.856**	0.836	0.240	0.117*	-0.074	0.051	0.000	-0.038	-0.083	-0.424	62.796**
16	79156AXWGL1063	-2.066*	3.340	0.236	-0.093	-0.101	0.100	-0.749 **	-0.267**	-0.109*	0.750	-0.357	3.630
17	79156AXMTU1156	-1.016	-5.460**	-0.114	-0.185	-0.045	-0.017	0.235	-0.184	0.084	-0.583	0.259	-0.537
18	79156AX MTU11-320-20	1.068	-4.144*	-8.331**	-0.080	0.134*	-0.254*	-0.315	0.108	-0.039	-0.583	-0.857**	9.463
19	79128AXRR3	-0.832	1.793	2.461	-0.041	0.073	-0.153	0.342	0.238*	0.069	-0.028	0.834**	-14.593
20	79128AXRR15	-0.099	-2.357	-7.106**	0.132	-0.002	0.067	-0.158	-0.187	-0.059	-0.194	1.068**	32.074**
21	79128AXRR17	-0.966	1.126	3.994**	-0.190	-0.014	-0.088	-0.058	0.022	0.029	-0.028	0.868**	25.574*
22	79128AXRR23	-0.082	4.276*	7.311**	-0.025	-0.044	0.069	0.017	-0.153	0.012	1.306**	0.618**	17.074
23	79128AXRR32	-2.432*	0.859	-6.572**	-0.086	0.103	-0.208	-0.025	0.088	0.014	0.472	0.551**	83.741**
24	79128AXRR50	-0.532	2.259	-1.456	0.117	0.040	-0.004	0.308	-0.003	0.031	-0.528	0.284	-65.426**
25	79128AXRR55	2.084*	1.943	-4.106**	0.107	-0.035	0.131	0.192	0.038	0.002	0.139	0.668**	-41.259**
26	79128AXRR65	-0.699	-2.574	7.211**	0.507**	0.013	0.249*	-0.008	0.030	-0.114**	-0.694	0.718**	17.074
27	79128AXWGL347	1.984	-1.207	4.928**	0.015	-0.044	0.086	-0.200	-0.062	-0.039	-0.361	-0.532**	-46.259**
28	79128AXWGL616	0.951	-2.224	4.111**	-0.121	-0.035	-0.003	0.233	0.197*	0.066	-0.028	-0.499*	-5.426
29	79128AXWGL674	0.434	-8.057**	-10.422**	-0.370**	-0.054	-0.114	-0.118	-0.078	0.059	-0.028	-0.482*	-41.259**
30	79128AXWGL676	-0.449	-3.307	-10.539**	-0.250	0.005	-0.149	-0.583*	-0.203*	-0.046	-0.028	-0.482*	-21.259
31	79128AXWGL705	-0.866	-5.807**	-8.339**	0.064	0.041	-0.043	-0.208	-0.178	-0.046	0.806	-0.582**	56.241**
32	79128AXWGL739	-0.649	-2.124	-9.056**	-0.123	-0.040	0.012	-0.058	-0.037	0.014	-0.028	-1.166**	-8.759
33	79128AXWGL810	0.418	1.359	4.361**	-0.076	-0.062	0.076	0.008	-0.062	0.017	-0.028	-0.632**	-7.926
34	79128AXWGL1063	1.568	3.993*	4.961**	0.185	-0.030	0.044	0.408	0.297**	0.036	-0.694	-0.216	15.407
35	79128AXMTU1156	-1.082	7.793**	11.261**	0.179	0.086	-0.053	-0.058	0.155	-0.046	0.472	0.201	-11.259
36	79128AX MTU11-320-20	1.251	2.259	6.994**	-0.026	-0.060	0.081	-0.033	-0.103	0.001	-0.528	-1.216**	16.241
37	68897AXRR3	-0.952	-8.082**	-10.497**	-0.004	0.005	-0.015	0.049	-0.038	0.002	-0.389	-0.677**	-49.037**
38	68897AXRR15	0.081	-5.082**	3.036*	-0.010	0.055	-0.080	0.074	0.037	0.009	-0.056	-1.144**	-72.370**
39	68897AXRR17	1.665	3.501	-1.864	0.158	-0.096	0.245*	0.074	-0.080	-0.018	0.611	-1.594**	23.630*
40	68897AXRR23	1.698	2.951	9.553**	-0.252	0.049	-0.229	-0.401	-0.005	-0.025	-1.556**	-0.594**	0.130
41	68897AXRR32	3.248**	4.184*	6.669**	-0.134	0.005	-0.090	0.457*	-0.263**	0.122**	-0.389	-0.810**	-38.204**
42	68897AXRR50	-0.052	0.034	-7.864**	-0.140	-0.078	0.058	-0.310	0.095	-0.026	0.111	-0.727**	57.630**
43	68897AXRR55	0.615	3.768*	12.036**	0.375**	0.082	0.053	-0.476*	0.062	-0.150**	0.278	-1.144**	66.796**
44	68897AXRR65	2.681*	4.551*	0.303	-0.740**	0.035	-0.454**	0.074	-0.096	0.180**	-0.056	-0.844**	-49.870**
45	68897AXWGL347	-3.135**	0.168	-10.581**	-0.167	0.014	-0.117	0.282	0.087	0.084	-0.222	1.156**	56.796**
46	68897AXWGL616	-0.319	2.151	-5.747**	0.171	0.042	0.020	-0.235	-0.155	-0.076	0.111	0.390	-29.870*
47	68897AXWGL674	-0.235	5.518**	0.819	0.198	0.029	0.058	0.014	0.045	-0.043	-0.389	0.706**	96.796**
48	68897AXWGL676	-2.269*	-0.282	14.053**	0.328*	-0.063	0.308*	0.299	0.145	-0.023	0.111	0.156	1.796
49	68897AXWGL705	-1.835	1.618	8.753**	0.016	0.014	-0.020	-0.126	0.170	-0.028	-0.056	0.606**	9.296
50	68897AXWGL739	-0.669	-0.999	1.536	0.345**	0.007	0.170	-0.226	-0.063	-0.103*	0.611	1.273**	14.296
51	68897AXWGL810	-0.802	-6.216**	- 5.197**	-0.164	-0.055	-0.002	-0.060	0.062	0.020	0.111	1.056**	-54.870**
52	68897AXWGL1063	0.498	-7.332**	-5.197**	-0.092	0.072	-0.144	0.340	-0.030	0.074	-0.056	0.573**	-19.037
53	68897AXMTU1156	2.098*	-2.332	-11.147**	0.006	-0.041	0.070	-0.176	0.029	-0.038	0.111	-0.460*	11.796
54	68897AX MTU11-320-20	-2.319*	1.884	1.336	0.106	-0.073	0.173	0.349	-0.005	0.039	1.111*	2.073**	-25.704*

* and ** significant at 5% and 1% level, respectively

lines and among restorers RR23, WGL 1063, WGL 676, RR 15, WGL 705, RR 17, WGL 674.(**Table 3**) Eleven hybrids 68897 A x RR 23, 68897 A x RR 32, 79128 A x WGL 616, 79156 A x RR 3, 79128 A x RR 17, 68897 A x WGL 616, 79156 A x RR3, 79156 A x WGL 347,79156 A x WGL 674, 79128 A x WGL 810 exhibited significant *sca* effects (**Table 4**). Tiwari *et al*. (2011) observed that several hybrids had high *sca* effects for grain yield in rice.

In the present study, both general and specific combing ability effects were estimated for various quality attributes (**Table 3 and 4**). For hulling recovery, significant positive value of *gca* effects exhibited among female and male parents *viz*., 68897 A and WGL 616 and WGL 810. While, significant positive *sca* effect was recorded by six hybrids *viz.,* 68897 A x RR 32 and 79156 A x WGL 676. For milling recovery 79128 A among lines and WGL 616, RR 15, WGL 810 and WGL 705 in testers exhibited significant positive *gca* effect implying their good general combining ability which may be utilized in breeding programmes for improvement of this trait (**Table 3**). Twelve hybrids registered significant *sca* effects in desired direction *viz*., 79128 A x MTU 1156, 79156 A x RR 15 and 79156 A x RR 3 for milling recovery.

In case of head rice recovery, significant positive value of *gca* effect among the female parents was exhibited by 68897A and among males WGL616, RR15, WGL810, WGL676, RR50, WGL739, WGL705 and RR23, respectively (**Table 3**). Significant positive *sca* effect was revealed by 21 hybrids *viz.,* 68897A x WGL676 (14.05), 68897A x RR55(12.03),79128A x MTU 1156(11.26), 79156A x WGL674 (9.60) and 68897A x RR23(9.55) respectively(**Table 4**). Both positive and negative *sca* effects in various cross combinations of 68897A were also reported by Thakare *et al.* (2013) and Showkat *et al.*(2015).

Positive *gca* effect for kernel length among lines was exhibited by 79156 A, while pollen parents recorded significant positive *gca* effects *viz*., RR 50, RR 55, WGL 739 and WGL 705 (**Table 3**). Significant positive *sca* effect for kernel length was revealed by 79128 A x RR 65, 68897 A x RR 55, 68897 A x WGL 676, 68897 A x WGL 739 (**Table 4**). Priyanka *et al.* (2014) reported negative *gca* effect and poor combiner for kernel length. Kernel length after cooking showed significant *gca* effect by 79156 A and among the male parents *viz.,* WGL 676, RR 50, WGL 739 and RR 55. Among the hybrids none of the hybrids recorded significant *sca* effects in desired direction for kernel width, length/breadth ratio and kernel length after cooking. Among the female parents 79156A, among male parents WGL 676 and hybrids 68897 A x RR 65, 68897 A x RR 32, 79156 A x RR 55 and 79156 A x WGL 739 recorded significant *gca* and *sca* effects, respectively for the character kernel elongation ratio.

Intermediate alkali spreading value indicated the medium disintegration and classified as intermediate gelatinization temperature which is highly desirable for quality grain (Shivani *et al.,* 2009). For alkali spreading value 79156A among female and among males WGL 676, WGL 705, WGL 810 and RR 17 recorded significant positive *gca* effects. Among hybrids 79128 A x RR 23 and 68897 A x MTU 11-320-20 recorded high *sca* effect. In case of water uptake, 79128 A and 68897 A among lines and in male parents WGL 676, MTU 1156, RR3, RR23, WGL 616 and RR 17 exhibited significant *gca* effect. Fourteen hybrids showed significant *sca* effect *viz*., 68897A x WGL 674 followed by 79128 A x RR 32, 68897 A x RR 55, respectively. For volume expansion ratio 68897 A and in testers WGL 676, MTU 1156, RR 3, RR 23, WGL 616 and RR 17 were good general combiners and hybrids 68897 A x MTU 11-320 and 68897A x RR32, were good specific combiners.

None of the parents showed significant desirable *gca* effects simultaneously in desired direction for all the traits studied. Among the lines 68897A showed significant *gca* effects in desired direction for days to 50% flowering, effective tillers, flag leaf length, flag leaf width, panicle density, yield/plant, hulling percent, head rice recovery, kernel width after cooking, water uptake and volume expansion ratio . Among the male parents, RR 15 was found to be good combiner for panicle length, filled seeds /panicle, unfilled seeds/panicle, self fertility, test weight, milling percent, yield/plant, Though different parents were found to be good general combiner for different characters, the results indicated that there was close relationship between mean performance of the parents and *gca* effect in most of the cases studied (Akanksha and Jaiswal, 2019). None of the crosses showed significant specific combining ability effects for all the traits in desired direction but some crosses showed good *sca* effects for important yield components and quality traits. The cross 68897 A x RR 23 showed highest significant *sca* effect for grain yield/plant and also recorded significant *sca* effect for component traits *viz*., effective tillers, plant height, flag leaf length, kernel length and head rice recovery, while 68897 A x RR 55 for grain yield/plant, effective tillers, plant height, unfilled seeds/panicle, self fertility, milling percent, head rice recovery, kernel length, milling percent, panicle length, panicle density in desired direction for yield and quality traits.

The present study revealed that, among the parents 68897A and RR15 recorded significant *gca* effect in desired direction for important yield and quality traits, while the cross combination 68897 A x RR 23 evinced the highest significant value of *sca* effect for grain yield/plant. The hybrids, 68897 A x RR55, 68897 A x RR 32, 68897 A x RR 15, 79156 A x RR 3 recorded desirable value of *sca* effects for most of the yield components and quality traits. The hybrids which recorded positive and significant *sca* effects in the present study needs to be further tested in observational/multi locational trials to exploit their heterotic potential at commercial level.

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